James Webb Space Telescope: The First Light Machine

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ABSTRACT

Scheduled to begin its 10 year mission no sooner than 2013, the James Webb Space Telescope (JWST) will search for the first luminous objects of the Universe to help answer fundamental questions about how the Universe came to look like it does today. At 6.5 meters in diameter, JWST will be the world’s largest space telescope. This talk reviews science objectives for JWST and how they drive the JWST architecture, e.g. aperture, wavelength range and operating temperature. Additionally, the talk provides an overview of the JWST primary mirror technology development and fabrication status.
**Origins Theme’s Two Fundamental Questions**
- How Did We Get Here?
- Are We Alone?

**Search for life outside the solar system**
- Search for other planetary systems
- Search for habitable planets
- Identify remotely detectable bio-signatures
- Search for "smoking guns" indicating biological activities

**Missions Supporting the Origins Goals**

**How Did We Get Here?**

**Are We Alone?**

**JWST Summary**
- **Mission Objective**
  - Study origin & evolution of galaxies, stars & planetary systems
  - Optimized for near infrared wavelength (0.6 - 28 μm)
  - 8 year Mission Life (10 year Goal)
- **Organization**
  - Mission Lead: Goddard Space Flight Center
  - International collaboration with ESA & CSA
  - Prime Contractor: Northrop Grumman Space Technology
  - Instruments:
    - Near Infrared Camera (NIRCam) - Univ. of Arizona
    - Near Infrared Spectrometer (NIRSpec) - ESA
    - Mid-Infrared Instrument (MIRI) - JPL/ESA
    - Fine Guidance Sensor (FGS) - CSA
  - Operations: Space Telescope Science Institute

**JWST Requirements**
- **Optical Telescope Element**
  - 25 sq meter Collecting Area
  - 2 micrometer Diffraction Limit
  - < 50K (~35K) Operating Temp
- **Primary Mirror**
  - 6.6 meter diameter (tip to tip)
  - < 25 kg/m² Areal Density
  - < $4 Million Areal Cost
  - 18 Hex Segments in 2 Rings
  - Drop Leaf Wing Deployment
- **Segments**
  - 1.315 meter Flat to Flat Diameter
  - < 20 nm rms Surface Figure Error

**A Vision for Large Telescopes & Collectors**
- Toward Accomplishing... the Impossible!
  - 100-1000m diameter
  - 20-40m diameter
  - ~10m diameter
  - 2.4m diameter
  - HST, TPF, SAFIR
  - JWST, TP, TFI
  - Conceptual
  - Imagination

**How Did We Get Here?**

**Trace Our Cosmic Roots**
- Formation of galaxies
- Formation of stars
- Formation of heavy elements
- Formation of planetary systems
- Formation of life on the early Earth
OTE Architecture Concept

Investments Have Reduced Risk

JWST Technology Demonstrations for TNAR

Technology Development of Large Optical Systems

AMSD – Ball & Kodak

Advantages of Beryllium

Figure Change: 30-55K Operational Range

Mirror Manufacturing Process

Mostly, Mass – Saves Money
High Conductivity & Below 100K, CTE is virtually zero.
Thermal Stability

Beryllium

Surface Figure With Alignment Compensation

Residual with 36 Zernikes Removed

ULE Glass

Beryllium Optical Performance
Ambient Fig 47 mm rms (initial)
Ambient Fig 20 mm rms (Base)
20K – 30K 77 mm rms
25K – 30K 7 mm rms

ULE Optical Performance
Ambient Fig 38 mm rms (initial)
20K – 30K 188 mm rms
25K – 30K 20 mm rms
XRCF Facility Upgrades in FY '05-06

XRCF CCS Assembly

1 of 3 Shrouds rough cleaning
1 of 3 floors move into clean room
Shrouds move into clean room

XRCF CCS Fit-Check

JSC Chamber A Thermal Vacuum Facility

Chamber A was used for Apollo landers and already includes nitrogen and helium systems. Plan is to upgrade it with a new helium base shroud and helium refrigeration.

XRCF Facility With Be AMSD II Mirror

JWST I&T

JSC Chamber A
Chamber size 55' diam, 117' high
Existing Shrouds LN2 shroud, GHe panels
Chamber Cranes 4x25t fixed, removable
Chamber Door 40' diam
High bay space ~102'L x 71'W

JWST Launch and Deployment

JWST is folded into stowed position to fit into the payload fairing of the Ariane V launch vehicle
Several subsystems deploy during transit to its L2 orbit

JSC “Cup Up” Test Configuration

JSC Size, Accessibility, and Large Side Door Access Make it Well Suited for This Configuration
When and how did reionization occur?

Reionization happened at $z \geq 6$ or 1 billion years after Big Bang.

WMAP says maybe twice?

Probably galaxies, maybe quasar contribution

JWST Observations:
Spectra of the most distant quasar
Spectra of first galaxies

First Light: Observing Reionization Edge

End of the dark ages: first light and reionization

First galaxies are small & faint
Light is redshifted into infrared.
Low-metallicity, massive stars.

JWST Observations
Ultra-Deep NIR survey (1.4 uJy), spectroscopic & Mid-IR confirmation

First Light
What did the first stars galaxies to form look like?
We don't know, but models suggest first stars were very massive!

Infrared Light
Light from the first galaxies is redshifted from the visible into the infrared.

The Hubble Deep Field

How do we see first light objects?

Deep Imaging: Look for near-IR drop-outs

JWST is designed to routinely operate in the deep survey imaging mode
New Results from UDF

How do we see first light objects?
The first stars may be detected when they became bright supernovae. But, they will be very rare objects!

Images of 2) redshift-6 galaxies taken from the UDF

The Renaissance after the Dark Ages

Hubble Ultra Deep Field

Sensitivity Matters

GOODS CDFS - 13 orbits
HUDF - 400 orbits

The Hubble Sequence

Hubble classified nearby (present-day) galaxies into Spirals and Ellipticals.

The Hubble Space Telescope has extended this to the distant past.

The Hubble Sequence form?
How did the heavy elements form?

Galaxy assembly is a process of hierarchical merging
Components of galaxies have variety of ages & compositions
JWST Observations:
NIRCam Imaging
Spectra of 1000s of galaxies

Distant Galaxies are "Train Wrecks"
**Unusual objects**

- How do proto-stellar clouds collapse?
  - Stars form in small regions collapsing gravitationally within larger molecular clouds.
  - Infrared sees through thick, dusty clouds.
  - Proto-stars begin to shine within the clouds, revealing temperature and density structure.

**Clusters of Galaxies**

- How does environment affect star-formation?
  - Massive stars produce wind & radiation.
  - Either disrupt star formation, or cause it.

**Birth of Stars and Proto-planetary Systems**

- How are circumstellar disks like our Solar System?

**JWST Observations**

- Deep NIR and MIR imaging of dark clouds and proto-stars.

- Survey dark clouds, "elephant trunks" and star-forming regions.

- Observations of dark clouds, "elephant trunks" and star-forming regions.

- Birth of stars and proto-planetary systems:
  - How do planets form?

**JWST Observations**

- Giant planets could be signpost of process that create Earth-like planets.

**JWST Observations**

- Solar System primordial disk is now in small planets, moons, asteroids and comets.

**JWST Observations**

- Coronagraphy of exoplanets

- Compare spectra of comets & circumstellar disks.
Planetary systems and the Origins of Life

How are habitable zones established?
Source of Earth's H2O and organics is not known.
Comets? Asteroids?

History of clearing the disk of gas and small bodies.
Role of giant planets?

JWST Observations:
Comets, Kuiper Belt Objects
Icy moons in outer solar system

Planetary Systems and the Origins of Life

Atmospheres of Extrasolar Planets

Bio Markers
Spectroscopic Indicators of Life
Absorption Lines
CO2
Ozone
Water
"Red" Edge

Countdown to Launch
Planned for 2013 Launch

Any Questions?